NASA Innovative Advanced Concepts

Orbiting Rainbows

Completed Technology Project (2014 - 2016)

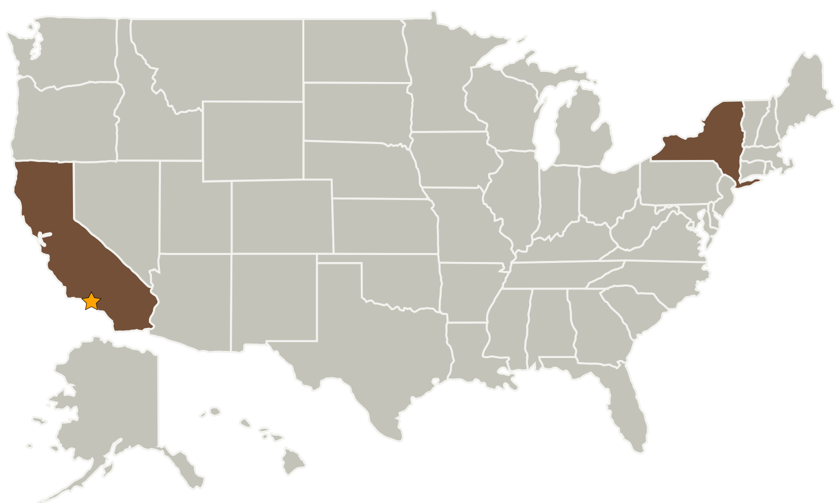
Project Introduction

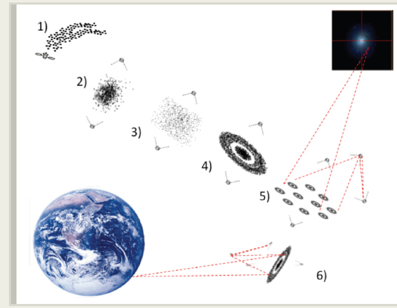
Inspired by the light scattering and focusing properties of distributed optical assemblies in Nature, such as rainbows and aerosols, and by recent laboratory successes in optical trapping and manipulation, we propose a unique combination of space optics and autonomous robotic system technology, to enable a new vision of space system architecture with applications to ultra-lightweight space optics and, ultimately, in-situ space system fabrication. The concept is to optically manipulate and maintain the shape of an orbiting cloud of dust-like matter so that it can function as an adaptable ultra-lightweight surface.

Anticipated Benefits

Allows building of apertures at a reduced cost, enables extremely fault-tolerant apertures that cannot otherwise be made, and directly enables classes of missions for exoplanet detection based on Fourier spectroscopy with tight angular resolution and innovative radar systems for remote sensing. In this task, we will examine the advanced feasibility of a crosscutting concept that contributes new technological approaches for space imaging systems, autonomous systems, and space applications of optical manipulation.

Primary U.S. Work Locations and Key Partners





Concept diagram

Table of Contents

Organizations Performing Work	Role	Type	Location
⭐Jet Propulsion Laboratory(JPL)	Lead Organization	NASA Center	Pasadena, California
California Institute of Technology(CalTech)	Supporting Organization	Academia	Pasadena, California
Polytechnic of Milano, Italy	Supporting Organization	Academia	Milano, Outside the United States, Italy
Polytechnic of Torino, Italy	Supporting Organization	Academia	Torino, Outside the United States, Italy
Rochester Institute of Technology(RIT)	Supporting Organization	Academia	Rochester, New York
University College London	Supporting Organization	Academia	Dorking, United Kingdom
University of Parma	Supporting Organization	Academia	Parma, Outside the United States, Italy
University of Rochester	Supporting Organization	Academia	Rochester, New York

Primary U.S. Work Locations	
California	New York

Project Transitions

September 2014: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Jet Propulsion Laboratory (JPL)

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

Eric A Eberly

Principal Investigator:

Bruno M Quadrelli

Co-Investigators:

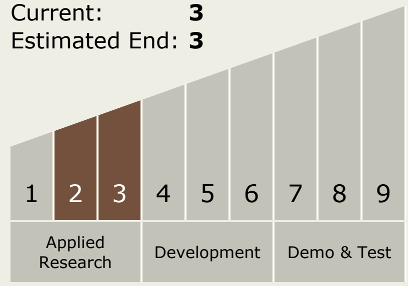
Darmindra D Arumugam
Scott A Basinger
Grover Swartzlander

September 2016: Closed out

Closeout Summary: Inspired by the light scattering and focusing properties of distributed optical assemblies in Nature, such as rainbows and aerosols, and by recent laboratory successes in optical trapping and manipulation, we propose a unique combination of space optics and autonomous robotic system technology, to enable a new vision of space system architecture with applications to ultra-lightweight space optics and, ultimately, in-situ space system fabrication. Typically, the cost of an optical system is driven by the size and mass of the primary aperture. The ideal system is a cloud of spatially disordered dust-like objects that can be optically manipulated: it is highly reconfigurable, fault-tolerant, and allows very large aperture sizes at low cost. This new concept is based on recent understandings in the physics of optical manipulation of small particles in the laboratory and the engineering of distributed ensembles of spacecraft swarms to shape an orbiting cloud of micron-sized objects. In the same way that optical tweezers have revolutionized micro- and nano-manipulation of objects, our breakthrough concept will enable new large scale NASA mission applications and develop new technology in the areas of Astrophysical Imaging Systems and Remote Sensing because the cloud can operate as an adaptive optical imaging sensor. While achieving the feasibility of constructing one single aperture out of the cloud is the main topic of this work, it is clear that multiple orbiting aerosol lenses could also combine their power to synthesize a much larger aperture in space to enable challenging goals such as exo-planet detection. Furthermore, this effort could establish feasibility of key issues related to material properties, remote manipulation, and autonomy characteristics of cloud in orbit. There are several types of endeavors (science missions) that could be enabled by this type of approach, i.e. it can enable new astrophysical imaging systems, exo-planet search, large apertures allow for unprecedented high resolution to discern continents and important features of other planets, hyperspectral imaging, adaptive systems, spectroscopy imaging through limb, and stable optical systems from Lagrange points. Furthermore, future microQminiaturization might hold promise of a further extension of our dust aperture concept to other more exciting smart dust concepts with other associated capabilities. Our objective in Phase II was to experimentally and numerically investigate how to optically manipulate and maintain the shape of an orbiting cloud of dust-like matter so that it can function as an adaptable ultra-lightweight surface. Our solution is based on the aperture being an engineered granular medium, instead of a conventional monolithic aperture. This allows building of apertures at a reduced cost, enables extremely fault-tolerant apertures that cannot otherwise be made, and directly enables classes of missions for exoplanet detection based on Fourier spectroscopy with tight angular resolution and innovative radar systems for remote sensing. In this task, we have examined the advanced feasibility of a crosscutting concept that contributes new technological approaches for space imaging systems, autonomous systems, and space applications of optical manipulation. The proposed investigation has matured the concept that we started in Phase I to TRL 3, identifying technology gaps and candidate system architectures for the space-borne cloud as an aperture. Summarizing the findings, we found that the technology enabling the Granular Imager is feasible, but is also complex and requires advancements in different areas. During Phase II, technology readiness levels for the various component technologies were determined, as well as mass, power, and cost for a representative system configuration. The wavefront control process follows the following steps of a multistage control architecture: Granular Cloud Shaping, Sub Aperture Coarse Alignment, Figure Control, and Computational Imaging. The main application considered was a reflective imaging system for astrophysics, but many unexplored applications of gran

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

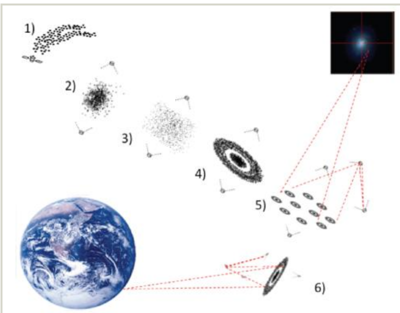
Primary:

- TX07 Exploration Destination Systems
  └ TX07.2 Mission Infrastructure, Sustainability, and Supportability
    └ TX07.2.3 Surface Construction and Assembly

Target Destination

Earth

Images



Orbiting Rainbows Concept
Concept diagram
(https://techport.nasa.gov/image/102263)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html